Agricultural Research Institute, Pusa.

THE MILLING AND BAKING QUALITIES OF INDIAN WHEATS

No. 3

SOME NEW PUSA HYBRIDS TESTED IN 1910

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PREFACE.

DURING the past three years samples of Indian wheats grown at Pusa and other places in India have been sent by us to England for complete milling and baking tests. The results obtained in 1908 and 1909 have already been published and have attracted considerable attention in India. During the current year a set of new Pusa wheats obtained by hybridization has been tested and the results are described in the present paper.

It appears desirable at this stage to sum up the position and to indicate the progress that has been made in this subject at Pusa up to the present time.

We are indebted to Dr. J. W. Leather, Imperial Agricultural Chemist, for the large number of nitrogen determinations involved in these investigations.

In the milling and baking aspect of the subject we have been fortunate enough to secure the invaluable assistance of Mr. A. E. Humphries, formerly President of the Incorporated National Association of British and Irish Millers, and a well-known authority on these questions.

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The Milling and Baking Qualities of Indian Wheat.

CHAPTER 1.

Introduction.

The first milling and baking tests of Indian wheat were carried out by Messrs. MacDougal Brothers in London in 1882.[1] Two Durum wheats from Bundelkhand and Bombay and two soft common wheats from the Meerut and Muzaffarnagar Districts were milled, both under mill stones and also by the roller system which was at that time a novelty in Great Britain. In their report Messrs. MacDougal state that "there is no probability of the Indian wheats coming into demand for manufacture into flour without a liberal admixture of other wheats. They all possess in a marked degree the same characteristics of great dryness and a distinct beany and almost aromatic flavour inseparable from wheats grown in the climates and soils of the tropics. Also the flours are ricey, the texture of the breads is too coarse and the crust is hard and brittle." On the other hand their great soundness and dryness and the fact that they gave unprecedented yields of flour, ranging from 77·46 to 80·52 per cent., as against English 65·2 and American Spring 72·2, were great points in their favour.

It is particularly unfortunate that these milling and baking tests were made only on two samples of bread wheats of the same class and also at a time of transition in the development of the milling industry of the United Kingdom when grinding under mill stones was beginning to give way to modern roller mills. As a result the cultivation of weak soft white wheats of the type of Muzaffarnagar (which are better suited to mill stones than to rolls) has since been consistently advocated in India and in consequence the growth for export of these sorts has increased. The

[1] *Wheat Production and Trade of India*, Calcutta, 1883.

requirements of the modern milling trade, which greatly prefers strong free milling wheats, have not been recognised and, as a result, the export trade in Indian wheats has proceeded on wrong lines. An idea has become prevalent that all Indian wheats are weak and sometimes do not behave well in milling. Their chief points of excellence are considered to be their great dryness and the thinness of the bran which circumstances enable a large proportion of flour to be obtained from them.

This was the position up to the year 1907 when we had occasion to make enquiries in the plains as to the class of wheats most in favour among the cultivators for their own consumption. The ryot invariably prefers a translucent sample and particularly likes those wheats which are dark in tint. The great resemblance of these Indian types to the stronger free milling wheats of North America and Russia led us to send ten samples to Mr. Humphries for complete milling and baking tests after the harvest of 1908. These ten wheats included three red wheats (Gujar Khan, Punjab Type 9, and Punjab Type 14) and five white wheats (Pusa 6, *Lal Kasar Wala*, three samples of Muzaffarnagar white, Australian 27, and Punjab Type 16). Of these the Muzaffarnagars, Australian 27, and Punjab Type 16 represented the soft weak white wheats while Punjab Type 9, Gujar Khan and *Lal Kasar Wala* were three translucent wheats much liked by the Punjab peasants. Pusa 6 was an amber coloured wheat, high in nitrogen, which had been grown from a single plant and which had been used as one of the parents in the first set of wheat crosses made at Pusa in 1906. This wheat gave the best results of the ten. It proved to be free-milling with a lively greyish-white granular flour which yielded a tough dough and large loaves with a superior crust and better general appearance than the bread from the other nine. After this the three Punjab wheats liked by the cultivators—*Lal Kasar Wala*, Punjab Type 9 and Gujar Khan—stood next on the list and proved to be much better wheats in all respects than the weak soft white Muzaffarnagars and Australian 27. The results proved that if the cultivator had been left to himself the types of wheats he would have selected for the export trade would have been more useful to the Home millers than the weak soft whites. Further the important fact became apparent that the class of wheat preferred in India by the people

is very similar to that in greatest demand in Europe while in addition the behaviour of Pusa 6 indicated that much stronger wheats than those usually grown might eventually be produced in India.

The publication of these results[1] attracted a considerable amount of attention in India and the subject was referred by the Director of Agriculture of the Punjab to the President of the Incorporated National Association of British and Irish Millers. The matter was considered in due course at a meeting of the Council of the Association, held in Mark Lane, and the deliberations which took place were published in the *Miller* of May 3rd, 1909. The result was that the recommendations based on Mr. Humphries' report were unanimously adopted by the most important Milling Association in the Empire while two of the largest Home Millers (Messrs. Nicholls and Rank) proposed and seconded the motion that was adopted.

In 1909, ten more Pusa selected wheats were sent to Mr. Humphries and two trade samples of Bombay Pissi and Jubbulpore Pissi, obtained from Messrs. Ralli Brothers, were included for comparison with the Pusa-grown wheats. These latter were weak soft white wheats largely grown for the export trade on the black cotton soils of Peninsular India. The report on these wheats was published early in the present year (1910), and the results obtained[2] amply fulfilled the promise of the previous report (Pusa Bulletin 14). The Pissis behaved poorly in the mill like Muzaffarnagar white but the majority of the Pusa selections gave exceedingly good results both in the milling and baking tests. Mr. Humphries summed up his report as follows:—

"From the foregoing remarks it will be gathered that several of the wheats sent me are very good. The most significant is No. 26 (Pusa 8). In No. 22 (White Jana Khar) regarded as typical of its group we have a wheat which looks really good and is so. It yields a granular lively flour, and in the estimation of most bakers a really stable and strong flour is granular. But in the case of No. 26 (Pusa 8) we have a flour which seems to be a compromise between the lively granular flour just mentioned, and the soft white flour such as that from the Pissis, yet it is really strong. If as a miller I could not have both, I would choose the White Jana Khar, but

[1] Howard and Howard, *Bulletin 14, Agr. Research Inst., Pusa*, 1908.

[2] Howard and Howard, *Bulletin 17, Agr. Research Inst., Pusa*, 1910.

many millers would not, and it seems to me that No. 26 (Pusa 8) should be tested exhaustively in several districts. It is in my opinion a most promising wheat. Several others are also well worth attention, and I hope that from among the very best, or from among the merely better sorts of those submitted to me, one or several may be found to give the best possible yields of grain and money to the producer in many or all parts of India."

Two of the best wheats, Pusa 22 (White Selected Jana Khar) and Pusa 23 (Red Selected Jana Khar), were used as one of the parents in the crosses made at Pusa in 1906. Some of the others, especially Pusa 7, Pusa 8 and Pusa 12, have given very high yields of grain at Pusa and are wheats of great promise from the agricultural point of view.

During the season 1909-10 the Pusa selections already tested in England were sown on large plots at Pusa and every precaution was taken to avoid errors in the determination of the yield. In addition some of the new wheats obtained by crossing and in which the high grain qualities of Pusa 6, Pusa 22 and Pusa 23 have been combined with the high yielding power of Muzaffarnagar and Punjab Type 9 were also grown on large plots under uniform conditions and a few of these were sent to England for milling and baking tests during the present year. The result of the tests of these new wheats is given below.

CHAPTER 2.

The Milling and Baking Tests of 1910.

Twenty-nine samples of Indian wheat were sent to Mr. Humphries for complete milling and baking tests in 1910. Twenty of these (ten Muzaffarnagars and ten samples of Pusa 20) are concerned with an investigation, in collaboration with Mr. H. M. Leake, Economic Botanist to the Government of the United Provinces, on the influence of the environment on the milling and baking qualities of wheat in India. The report on these 20 samples will be published separately. The other nine wheats, the tests of which form the subject of this chapter, are as follows:— Three, namely, Pusa 1, Pusa 3 and Pusa 4, are selections grown at Pusa. Two, No. 1 Mastung and Red Quetta, are samples of Baluchistan wheats which have been tested in order to verify the alleged existence of strength in the wheats from Mastung and their superiority over those grown at Quetta. The remaining four—Pusa 100, Pusa 101, Pusa 102 and Pusa 106—are new hybrids raised from the crosses made at Pusa in 1906. Pusa 100 and Pusa 101 were obtained by crossing Muzaffarnagar white with Pusa 22 (White Selected Jana Khar). Pusa 102, a red wheat, was produced from a cross between Punjab Type 9 and Pusa 23 (Selected Red Jana Khar). Pusa 106 was produced from a cross between Muzaffarnagar white and Pusa 6. The appearance of the grain of the crosses from the three Pusa selections in all cases resembles that of one of the parents, namely, Pusa 6, Pusa 22 and Pusa 23. There is no resemblance to the Muzaffarnagar parent and it will be seen below that none of the undesirable Muzaffarnagar characteristics were disclosed in the milling and baking tests.

The nitrogen determinations of these wheats which were made by Dr. J. W. Leather, Imperial Agricultural Chemist, are given in the table on following page:—

No.	Name.	Where grown.	Colour.	Weight of 1,000 grains in grammes.	Nitrogen, per cent.
1	Pusa 1	Pusa	Red	36·73	2·32
2	Pusa 3	„	White	48·95	2·42
3	Pusa 4	„	„	45·67	2·25
4	No. 1 Mastung	Mastung	Fixed	40·00	1·90
5	Red Quetta	Quetta	„	35·95	2·11
6	Pusa 100	Pusa	White	38·90	2·36
7	Pusa 101	„	„	39·80	2·30
8	Pusa 102	„	Red	37·57	2·35
9	Pusa 106	„	White	35·32	2·65

Mr. Humphries' report on these wheats is given below:—

Report by Mr. A. E. Humphries, Past President of the Incorporated National Association of British and Irish Millers, on the 29 samples of wheat sent from India in 1910.

"In accordance with arrangements previously made I have examined, milled and baked the twenty-nine sample lots of Indian wheat, and to illustrate important differences in quality have had a photograph made and coloured of loaves produced from two typical Indian flours for comparison with one produced from a typical Manitoba flour.

"In two previous seasons I have done similar work for the Indian Government and the reports which I then made have been published in No. 7, Vol. II, and in No. 4, Vol. 3, 'Memoirs of the Department of Agriculture in India,' also in Bulletin No. 17 issued by the Pusa Agricultural Research Institute. Mr. and Mrs. Howard have also included them in their book entitled 'Wheat in India.' In the examination of the twenty-nine samples, I have followed generally the same methods described in those previous

reports. I therefore need not describe them in detail but can summarize them as follows:—Almost all the wheats were free from dirt and other extraneous matter, but in those cases where it was necessary I have cleaned the wheat by commercial methods. I have ascertained the natural moistures of the wheats on arrival and have 'conditioned' each lot according to its own requirements, so that in milling them I have sought to be in a position to obtain optimum separations of husk (bran) from kernel, and to affect in each case the quality of the resulting flour, so far as it can be affected, by the addition of varying percentages of water, operating in desirable differing periods of time upon the physical characteristics of the flour, and upon its chemical constitution through the effects of natural enzymes, which become active in the presence of added water. I have noted in detail the behaviour of each wheat in the grinding and separating processes of milling, a part of the entire examination to which I attach much importance, and have observed the appearance of each flour and the percentage of it obtained in each case. In baking I have followed the methods which I practice in testing such wheats for commercial purposes, and in each case have noted its behaviour in the dough stage, the appearance of the loaves as regards general appearance, size, shape, colour of crust and crumb, and flavour. In milling small lots of wheat experimentally it is impossible to ascertain with certainty the maximum quantity of bread which can be obtained from a given weight of flour, so I have made no attempt to determine that point. Nor under such conditions do I attempt to express an opinion on fine points, but I can and have come to very definite conclusions on the respective merits of the wheats and should not hesitate to act upon such conclusions if I were buying the wheats on a large commercial scale.

"It may be desirable to define and explain the following technical terms. A wheat is said to be red or white according to the colour of its skin (bran). The term red really implies varying shades of brown; the term white really means varying shades of yellow. In certain cases when the grains are also translucent, it is difficult to determine with precision whether a wheat is red or white, but such fine points are unimportant. The important one is that colour of skin is not directly correlated with colour of endosperm. A white wheat may enclose an endosperm which yields flour of an

intensely yellow hue, a red skin may enclose an endosperm which yields flour of a relatively very white hue. But even though, in still increasing degree, modern methods of milling are diminishing the amount of pulverization of husk (bran) in the manufacture of flour, a lot of bran powder is made in grinding, and it is obvious that such powder from a white wheat will discolour flour much less than bran powder from a red wheat. Furthermore, in many markets 'white' bran is worth more than 'red' bran. It has been commonly believed that red wheats are 'stronger' than white wheats, but there is no real warrant for such a belief either in fact or in theory. Colour of skin is one unit, quality of endosperm another, and there is no necessary correlation between them. The wheat breeder can handle these two points as separate Mendelian units, and is therefore able to produce, and is producing, white wheats which are very strong. Another popular misconception is that white wheats necessarily are soft and that it is difficult to effect easy separations in milling them. It is true that many white wheats are soft and behave badly in milling on account of their 'woolly' texture, but there is no inevitable correlation between a white skin and that bad point. A white wheat can be ideal as regards strength and as regards its behaviour in milling. There is therefore no valid objection against seeking to obtain the commercial advantages which incontestably belong to white wheats as a class, in combination with great strength and the desirable characteristic to which in a previous report I have applied the designation 'free-milling.'

"The term 'strength' has been loosely applied to cover essentially different characteristics. I have been careful to point out in previous communications that the 'capacity for making large shapely and therefore well aerated loaves' is one unit of quality and that the 'capacity for making a large quantity of bread from a given quantity of flour' is another. I am still using the former phrase as the definition of strength, although if I were dealing with fine points of scientific investigation, I would willingly admit that mere volume of loaf is not quite the same unit of quality or due to the same physical or chemical causes as shape of loaf. It seems to me, however, that such refinements of expression are unnecessary.

"By 'stability' I mean the facility with which large masses of dough can be handled in the 'bakehouse' which necessarily implies that they are free from stickiness. In considering the wheats of the world it is correct to say that this generally also implies toughness and resiliency, but as I am now dealing with Indians only the adverb 'generally' ought to be changed to 'frequently.' The ordinary Indian wheats of commerce yield doughs which are certainly 'stable,' but they are not tough or resilient. Those terms however can be applied to many of the new wheats which have been sent me in the last three seasons for testing purposes.

"For my last report on Indian wheats I invented the term 'free-milling.' Previously the terms hard and soft were used to denote a characteristic and its opposite but that caused confusion. Anyone would suppose that for milling a hard wheat more power would be required than for milling the same quantity at the same feed per hour of a soft wheat. But that is not necessarily true, if the entire process of milling be taken into account. The ease with which separations can be made between various grindings is a most important element in determining milling value and incidentally in affecting the power required to convert a wheat into its commercial constituents of flour and offal. Some wheats which are really soft are resolved into these commercial products with difficulty and by the use of much power, because the endosperm does not readily separate from the bran in grinding and because when the bran is removed, the endosperm is not reduced easily to the powder known as flour. A 'free-milling' endosperm, such as that possessed by Fife grown in England or elsewhere, requires a minimum amount of power to resolve its endosperm as semolina or middlings into a fine powder for it can be so reduced very rapidly by a few grindings, but a softer wheat may require a greater number of grindings and a much greater amount of separating surface in the 'dressing' machines, if the texture of the endosperm be 'woolly.' This term is expressive. Such an endosperm may be soft, and owing to the way in which its particles cling to each other it is most undesirable to apply great pressure if an optimum separation is to be obtained. Hence it may and probably would be better to give such wheaten products as many successive grindings as those from much harder wheats. But it is true that some hard wheats are also woolly in

texture and in those cases the difficulties in milling pertaining to woolly wheats are intensified. The elaborate and entirely proper system of adding water to wheat, known as 'conditioning,' does of course reduce the mere hardness of any wheat but, applied improperly, the miller 'gets out of the frying pan into the fire,' inasmuch as the wheat so treated may be made 'woolly' in texture or its inherent woolliness may be intensified, so that the difficulties of milling are increased instead of being decreased. In a miller's estimation therefore, and so far as the processes of milling cleaned wheat are alone concerned, the ideal wheat may be either hard or soft as long as the separation of endosperm from bran and the reduction of semolina and middlings into flour and offal can be easily effected. I have wished to amplify my previous communications on this point because it is important, and of the twenty-nine cases two, to which I will hereinafter refer, call for special comment in this connection. If I were asked to say which I would prefer, a 'free-milling' hard wheat or a 'free-milling' soft wheat, I should, having regard to the most modern facilities of manufacture, choose the former, though I would quite willingly buy the latter, but I would never buy either a hard or a soft 'woolly' wheat so long as I could get a 'free-milling' wheat at the same price, other points being equal, and I would only begin to contemplate buying a 'woolly' wheat if it could be bought at a substantially lower price than 'free-milling' ones. The colour of the resulting flour depends to an appreciable extent upon the facility with which the necessary separations in milling can be effected.

"In previous seasons I have invariably made the bread from the sample lots of wheat from flour, yeast, water and salt only. This year I have sought in the second or third bakings to develop the potentialities of the flours by using materials which operate directly as yeast foods or as agents affecting the gas-yielding constituents of the flour or the physical or chemical characteristics of the dough, whereby its gas retaining capacity may be improved materially and its distensibility increased. It is well known that the flavour of bread can be most beneficially affected in this way. I need not herein seek to justify any such procedure. Wheat is designed by Nature to be a seed. Man has diverted it from its original functions to use as a food. The chemical and physical characteristics

of various wheats differ very widely, partly from varietal causes, partly from the effects of various soils, climates and water supply. The yeast as a living organism has to obtain food. In favourable cases it can obtain all it wants from flour which has been subjected to no special treatment. In other cases, a change in the physical condition of the flour enables the yeast to get its necessary food so that a complete aeration of the dough can be effected. In other cases that desirable change in the physical condition of the flour is insufficient and a change in its chemical constitution is necessary, so that starch which is from physical reasons particularly stable or insusceptible to change, may be made susceptible to diastatic action whereby a sufficiency of yeast food may be made in fermentation, and those elements be therein produced, which confer on bread made from wheats grown in very hot dry climates a pleasant flavour. Or, taking another aspect, yeast must have mineral food in a form it can assimilate. The ash of different wheats varies considerably both as regards constitution and amount and those differences are greatly accentuated according to the grade or quality of the flours produced from them. Or taking still another aspect, the yeast requires nitrogenous food in a form which it can easily assimilate. The physical condition of the wheat and of the flour produced from it may be of very great influence in this problem. The husk (bran) contains much nitrogenous and mineral matter which may have a great and potent influence on the life and sustenance of the yeast plant or upon the physical condition of the gluten, but it is inextricably associated in the husk with other constituents, which, valuable as they are in Nature's scheme, wherein wheat is a seed, are undesirable in flour used for food purposes. It seems to me therefore not only legitimate, but desirable to utilise the latest discoveries of science to fit flour more perfectly for its functions as food even if the ideas current fifty or a hundred years ago concerning the manufacture of bread are superseded. With these ideas in my mind, I have had no hesitation in seeing whether by such treatment I could get rid of the dry unpleasant flavour, or lack of flavour, characteristic of bread made from Indian wheat, whether I could make larger and better looking loaves from it, and whether some of the new wheats produced at Pusa or elsewhere in India, which seem to possess the

same sort of characteristics as Manitoba wheat, could in fact be so affected, that the effects of long rainless periods of growth in India could be minimized and the same results attained as those which are obtained from Manitoba wheat, produced in a combination of high temperature and a greater supply of water. To attain such objects, I have used various malt extracts in which the relative diastatic, saccharifying and proteolitic activities are controlled, and other forms of what are generally called 'yeast foods.' It would obviously be unfair to give Indian wheats the benefits of such treatment and the competing wheat none of them, so in the trials made in this connection I have treated all the flours to the best advantage according to the present state of my knowledge. It also is obvious that it is extremely difficult to overcome, by a treatment lasting a few hours, the effects of several weeks or months, but I have no hesitation in saying that much good has been done and much more will probably be accomplished in the milling and baking processes for Indian wheat, if India produces varieties of wheat which are not only in themselves better than the varieties now ordinarily grown there, but those varieties possessing potentialities of quality which can be developed by the latest evolutions of milling and baking practice.

Baluchistan Wheats.

"The twenty-nine lots include two, named No. 1 Mastung and Red Quetta both of which I understand came from Baluchistan. The former sample contained mostly soft wheat, but it also contains some soft red and some hard red wheat. This lack of uniformity in texture is a bad point, one to which British buyers attach much importance. It behaves very well in the conditioning and milling processes. In the notes on appearance which I dictated as a first stage in these investigations I said 'nothing special at all in this sample. Should be surprised if it yields strong flour.' Nor does it. It is Indian wheat of an ordinary undistinguished type.

"The Red Quetta contains a large proportion of white wheat similar to the Mastung. The berries are irregular in shape and comprise some very hard, and some soft by Nature. This kind does not appear to be strong and it is not so. The description I have used concerning Mastung applies to Red Quetta also. The baker's

note concerning the flavour of the bread from these two kinds is 'Very dry, very chaffy. Tastes like flour itself.' The last remark, if inaccurate, is expressive. No wonder the natives prefer Durums to such varieties for their own food.

Pusa Nursery Lots.

"These were seven in number labelled Pusa 1, Pusa 3, Pusa 4, Pusa 100, Pusa 101, Pusa 102 and Pusa 106. Pusa 3 has the appearance of Talavera or Tuscan wheat. It is one of the worst cases I have ever come across of excessive 'woolliness' in texture. I suspected that when I first looked at it but said nothing to the miller who did the actual work of milling it. He strongly condemned it for that fault. The flour it yields is of a very good white hue in appearance, much better than any other of this group, but that superiority is not maintained in bread. The dough is stable and tough, the loaves of good volume and pleasant flavour, so that on all points but its behaviour in the mill this Pusa 3 is a very good wheat, but the bad point is so pronounced that in my opinion it will be fatal, if in another season it again occurs. I think this should be tried again another year before it is discarded, but on this year's results the Muzaffarnagar grown at the same place (Pusa) is preferable, all points considered. Of the six other wheats in this group, two, Nos. 1 and 102, are red. Both are of a very dark hue similar in that respect to the Red Jana Khar and Hara of my last year's report. The hue is not at first sight attractive but nevertheless these wheats 'take the eye.' Both behave very well in the mill. Pusa 1 yields a flour of brownish hue, and makes a tough dough. It reminds one of typical Russian Ghirka wheat which means that it is likely to work better in combination with other varieties than by itself. I have not tried it in combination, but used by itself the loaves are not large. No. 102 yields flour of a good yellow hue, makes very good doughs and loaves of good volume, good flavour and pleasing appearance. Of these two red wheats No. 102 is the better.

"The other four lots of the group are all white wheats. All are of very pleasing appearance. No. 4 has a small blemish inasmuch as some of the berries are dark, almost black, at a small point near

the germ, but this does not appear to be due to bad weather at harvesting or anything in the nature of smut, so I shall be curious to see whether it is accidental, due to some seasonal influence, or whether it is a characteristic of the variety. Apart from that blemish it has a very beautiful appearance and the importance of that fault must not be exaggerated. The three lots Nos. 100, 101 and 106 are very beautiful wheats also. On appearance only there is little to choose between them. If anything 106 may be the best looking. These three and Pusa 4 all behave very well indeed in the milling processes. The flours they all yield are granular, that is to say, they are bread flours rather than biscuit or pudding flours and should be judged by comparison with hard Spring Wheat flours from Minneapolis or Manitoba rather than by comparison with Muzaffarnagars or similar wheats. They are all flours possessing great potentialities as regards baking value, which can be developed by proper treatment during milling and baking on the special lines mentioned hereinbefore. Without this special treatment they behave very well in the dough and produce loaves of fair but not great volume, and of first rate appearance and flavour. They behave like Manitoban good grade wheats produced in a dry season. That is to say, they, like such Manitobans, respond very markedly to the addition of malt extract and 'yeast foods' and the volume of the loaf can be increased very greatly by the use of the right malt extract. They seem to be possessed of very good qualities, capable under favourable conditions of yielding extremely good results.

"I have not enough of these varieties left to see how they behave in combination with other wheats, but I believe they would do very well indeed under such conditions. At any rate I would as a buyer be prepared to pay substantially more money for them than for any of the ordinary Indian wheats of commerce.

"To give an illustration of the respective merits of these Pusa Nursery wheats and an ordinary Indian, I made a short preliminary series of trials to see how I could make the best possible loaves from a Muzaffarnagar, one of the Pusa Nursery group, and average Manitoban of the 1909 crop. I am told by Sir James Wilson that most of the Muzaffarnagar which reaches this country come forming a substantial part of the commercial kind known as Choice

Manitoba (No. 2 Northern).

Pusa 4.

Muzaffarnagar White.

LOAVES FROM CANADIAN AND INDIAN WHEATS.

White Kurrachee. For that reason I chose for this photograph the Lyallpur lot. The special treatment given to it has somewhat improved its appearance and flavour. Of the Pusa Nursery group I finally, after some hesitation, chose Pusa 4. Pusa 101 would have been my alternative choice. The Manitoba wheat was No. 2 Northern, milled in bulk separately. This had the advantage of being specially treated during milling in preference to the baking stage. The photograph will tell its own story. No housewife would hesitate a moment in her choice between the two Indians even before she tasted them, a blind man would choose the same loaf of the pair. It will also be seen that the best Indian does not attain the same volume as the Manitoba, but the flours are of the same type and in flavour and general appearance apart from size there is little to choose between them.

Summary.

"Of the Muzaffarnagars as a variety I hold the same opinion as heretofore. So long as they are in relatively small supply they will find a ready sale on our British markets, especially on those supplying districts where bread is mostly baked at home by housewives or their domestic servants. The variety of Durum known as Pusa 20 is a very good one of its type. It cannot on our markets take the place of Muzaffarnagars, nor is it ever likely to be in great demand here except at relatively low prices. Its recommendation for extended cultivation must be based not on the requirements of our British markets, but upon its behaviour from an agricultural point of view in certain districts of India. If on account of such considerations, it is desirable to produce a Durum wheat, this lot known as Pusa 20 will find greater favour, or at least arouse less antipathy, on British markets than the ordinary Durums of commerce. If any one of the Pusa Nursery group, except perhaps No. 3, be found to yield financial return to the grower as satisfactory as that derived from the ordinary Indian varieties now produced, it should be recommended for extended propagation, for such wheats will find great favour on our markets, and it is obvious that the reasons for recommending an extended propagation will be increased if some or all of them are first rate croppers. I am however obliged to draw particular attention to one point arising

out of these milling and baking trials. We have seen that surprisingly good results as regards quality are obtained at Pusa, both on the 'ordinary' wheat (Muzaffarnagar) and the Durum wheat (Pusa No. 20). It seems to me, therefore, that the best wheats of the Nursery group should be tested at various centres as soon as possible, and a final opinion as to the degree of their superiority over ordinary varieties should be delayed until such further trials are made. My present function is to write of things I know, but in view of the results obtained from the wheats grown at Pusa I am tempted to speculate upon the probable causes of such good results, and inasmuch as I know that in some countries great benefit to quality is caused by rain during the period of maturation or during harvest, I am wondering whether at Pusa the supply of water to the plant during the later stages of its growth has been by Nature or artificial means regulated to its real requirements: and if so, whether that is the cause of the improved quality from that centre.

"I was not commissioned to investigate the chemical constitution of these wheats, but for my own information I have ascertained that flour produced from a mixture of Pusa 100, Pusa 102 and Pusa 106 contained 2·21 per cent. nitrogen and that the flour produced from a mixture of several Muzaffarnagars contained 1·53 per cent. nitrogen.

"The flour from the No. 2 Northern Manitoba used for making the loaf which has been photographed contained 2·16 per cent. nitrogen. I had the flours themselves analysed, not the wheats from which they were made. These figures are very interesting. The nitrogen content of the Muzaffarnagars is not at all low for Indians. I have known flour made from the commercial grade of wheat known as Choice White Kurrachee to contain only 1·28 per cent. nitrogen. Some No. 2 Club Calcuttas recently yielded flour containing 1·38 per cent. The poor baking qualities of the Muzaffarnagars is not due exclusively or perhaps mainly to a low nitrogen content. Nor can the relative superiority of the Manitoba flour over the 'Pusa 4' be due to their chemical compositions as indicated by their respective nitrogen contents. I cannot herein enter upon any discussion of the scientific points involved, but I may say that we have in these cases another exemplification of the principle that the physical condition of a wheat or of some of its

constituents has a very great influence in determining its baking value."

ALBERT E. HUMPHRIES.

WEYBRIDGE, SURREY,

October 27th, 1910.

It will be seen that special attention has been drawn in the above report to the high qualities of the wheats grown at Pusa during the past three seasons. It does not seem out of place therefore to describe in detail the present methods adopted in growing this crop at Pusa and to give some account of the soil and climatic conditions of the tract in which Pusa is situated. These matters form the subject of the next section of this paper.

CHAPTER 3.

The Cultivation of Wheat in the Botanical Area at Pusa.

The climate of Pusa is typical of that of North Bihar and is characterised by three distinct kinds of weather. During the months of November, December and January the weather for India is cold and, as a rule, there is but little rainfall during this period. After the middle of February the temperature rapidly rises and by the end of the month the dry westerly winds which bring in the hot weather period are well established. The hot season lasts till June when the monsoon phase (characterised by high temperatures combined with high humidity, easterly winds and heavy rain) begins, extending to the end of September. October is a transition period between the damp hot monsoon and the drier cold weather. In the beginning of the month the *rabi* sowing rains, known as the *hathia*, occur, but these sometimes fail or are insignificant in amount. Except for the small rainfall at or about Christmas and during February the wheat crop derives its water supply from the moisture stored up in the soil during the monsoon period.

The soil at Pusa and in the neighbourhood is a greyish alluvium containing over 30 per cent. of calcium carbonate and a very small percentage of phosphoric acid. The physical character of the soil and its suitability for various crops depends largely on position. The high-lying lands are opener in texture, better drained and more freely working than the heavier low-lying fields. At the extreme limit in one direction are the heavy rice lands often flooded during the monsoon. At the other end are the high light lands under tobacco and *rahar* (*Cajanus indicus*) in the *rabi* season and under maize in the *kharif*. Between these extremes are to be found the soils best adapted for wheat and those just above the inundated rice fields grow wheat to perfection provided the previous cultivation is properly carried out. Such soils, *if well managed*, will absorb sufficient water during the monsoon to grow at least 40 bushels of wheat to the acre without manure and without rain or irrigation after sowing. At present the cultivators often do not get

more than a third of this due to the inferiority of their practice compared with that in the Botanical area at Pusa.

Wheat sowing begins about October 15th and should be completed by November 1st. Earlier sowing is not desirable on account of the injurious effect of the high temperature and high humidity on the seedlings during the interval between germination and tillering. At this stage the seedlings are provided with the first roots only and are not robust enough to withstand high temperatures combined with great dampness. At this period white-ants (*Termites*) often do considerable damage and destroy the seedlings wholesale by eating through the first internode. Possibly they are attracted by the soluble food materials either in the germinating seed or in transit to the leaves. Tillering begins about the middle of November after which growth is very rapid and the crop begins to come into ear early in January. Wheat is left standing till it is dead ripe. This facilitates the threshing process and the breaking up of the straw into small pieces (*bhusa*) under the feet of cattle. Ripening takes place under a rapidly ascending temperature and any late wheats are dried up by the hot winds which also favour rust attacks by lowering the resistance of the host plant.

Rust rarely appears on wheat at Pusa before the end of December when its spread depends on the weather. Damp cloudy weather with high humidity and east winds favour the fungus while dry west winds and bright weather have the reverse effect. Rust is also much more prevalent in any year on wheat sown on high light lands, in which the moisture supply is apt to give out, and also on late sown crops. If the crop is sown at the proper time on the right class of soil wheat will ordinarily set its seed before the period at which rust becomes dangerous. The crop is not entirely destroyed and a fair yield of grain is obtained unless the attack is very rapid and virulent. On late sown wheat and when the soil is too light a rust epidemic can do great damage and may even prevent the formation of any grain at all. We have been very much impressed by the heavy crops, for example, 40 bushels to the acre, which are often produced by fields which appear to be rather rusty. Wheat seems to stand a large amount of rust provided the attack is not too rapid.

High winds just after the wheat is in ear often do great damage, especially if the crop is a heavy one. All the wheats with weak straw are then badly laid which circumstance besides hindering ripening also favours rust. Wheats which have been irrigated are not laid so easily as dry crops, as in the former the surface soil is much more compacted. In some tracts of the alluvium the ryots increase the standing power of wheat by growing it mixed with *sarson* (*Brassica campestris*).

Our first attempts to grow wheat at Pusa during the *rabi* seasons of 1905-06 and 1906-07 ended in partial failure due almost entirely to the selection of the wrong type of land, to inadequate preparation of the soil and to the want of air drainage. Most of the cultures were attacked by rust to a great extent and in some cases were almost entirely destroyed by it. The cultivators, on the other hand, were more fortunate and certainly grew better and healthier wheat than was to be found on the Pusa Estate or on the Botanical area.

During the season 1907-08 heavier land was selected for the crop, a large number of trees and bamboo clumps, which had interfered with the air-drainage of the Botanical area, were removed and much better results were obtained. In 1908-09 and 1909-10 the present system of cultivation was evolved by which crops at least twice and often three times as great as those of the cultivators have been grown while the appearance and quality of the grain are very much better than anything to be found in the district.

Several causes have contributed to this result. In order of importance they are considered to be (1) hot-weather cultivation, (2) moisture conservation before and at sowing time, (3) the improvement of the physical condition of the soil by green manuring and embankment.

Hot-weather cultivation.—In Europe one of the first conditions of success in the proper management of arable land is early ploughing which results in the destruction of weeds and in the amelioration of the soil by the frosts of winter. The subsequent working of the land before sowing in the spring is rendered much easier by autumn ploughing and it is bad practice to let stubbles lie untouched for any length of time. In Bihar there is no winter and two crops are often grown on the same land in one year, so that European

practice does not apply at first sight. It occurred to us some years ago to substitute cultivation in the hot dry weather of India for the autumn ploughing of England, to open up the stubbles immediately after harvest and to plough them several times during the hot weather of April and May. The effect was instantaneous. Insect and fungoid pests tended to disappear or at least to become insignificant. The fertility of the land went up at once, the fields became cleaner and much more easily worked while a larger amount of moisture was absorbed by the soil during the subsequent monsoon. One area of land in the northern trial ground at Pusa has given increasingly heavy crops without manure for the last three years. Last season the third of these crops was the largest yet obtained and so great was the growth that many of the weak strawed local wheats could not stand up but were badly lodged. Another plot, previously under bananas, after efficient hot-weather cultivation gave exceedingly high yields without any manure, some of the small plots indicating a great deal over 30 maunds to the acre. Another high-lying field, regarded as poor land by the ryots, gave an average of nearly 30 maunds to the acre in 1909-10. In all these cases the crops were at least three times those grown by the cultivators in the land alongside the Botanical area.

It has become apparent that the first condition of success in wheat production at Pusa consists in efficient hot-weather cultivation. In previous papers we have suggested that one of the chief reasons of the increased fertility which results from hot-weather cultivation is to be found in the increased supply of available nitrogen due to an alteration in the soil flora and that the work of Russell and Hutchinson at Rothamstead will be found to apply to the alluvium of the Indo-Gangetic plain.[1] Whether this theory will be verified or not it is too early to venture an opinion. The subject is being investigated at Pusa and Cawnpore and the results will be published in due course. As regards the practical value of hot-weather cultivation in the Indo-Gangetic plain, however, there can be no doubt. We believe it will be found to be of universal application in the plains and will lead to the material progress of the people. In tracts where the surface has been hardened by irrigation and

[1] See Russell and Hutchinson, *Journ. of Agr. Science*, Vol. III, 1909, p. 111, and Howard and Howard, *Nature*, Feb. 17th, 1910.

where water is not available to soften the land, new ploughs or possibly harrows on the disc or spring-tooth principle, capable of breaking the hard surface, may have to be designed and manufactured. The country plough is useless for the purpose in the absence of irrigation water to soften the land. The best manner of exposing the soil of the alluvium to the sun and air in the hot weather is of such vast importance to the material progress of India that it is hoped it will be taken up by all the Provinces concerned.

The conservation of moisture.—The provision of canal water is in many respects not an unmixed blessing to India. Apart from the raising of the water level and the prevalence of malaria in irrigated tracts there is a tendency where canal water is available to overwater and to cover up, as it were, slovenly work by an extra watering. Water comes to be regarded as a kind of universal remedy and the more applied the better. Consequently it is in canal irrigated tracts that the worst cultivation is to be seen while on *barani* lands or where the water has to be raised from wells the standard of work generally and of moisture conservation in particular at once goes up. Overwatering is particularly harmful in the case of wheat as it not only diminishes the yield but also helps to ruin the appearance and milling qualities of the sample. Wheat is a crop adapted to dry cultivation and does not require a large amount of water.

At Pusa wheat is almost entirely grown on the moisture absorbed by the soil during the previous monsoon. The winter rains are small and sometimes fail altogether and irrigation water is now rarely used. The management of the land during the monsoon is designed to absorb as much water as possible, to prevent surface wash and to keep down weeds. The hot-weather cultivation enables all the early showers to sink into the ground and up to the middle of July the land is occasionally ploughed with iron ploughs and levelled with the *sohaga* (a flat beam of wood drawn over the ploughed surface by cattle, the driver standing on the beam). The object of this is to keep down weeds and to facilitate absorption of the rainfall. After the middle of July the wooden country plough only is used as this serves to pack the subsoil. At the end of the monsoon a dry hot spell often occurs until the sowing

rains (*hathia*) at the end of September. These rains however sometimes fail so that provision has to be made for a hot rainless period extending possibly from the end of August to October 20th. During such periods no ploughing is done but the surface is harrowed so as to produce a surface mulch under which the heavy lands dry slowly. This slow-drying under a harrowed surface is of great assistance in obtaining rapidly a good tilth just before sowing. If left to dry in the ordinary way large cracks are formed, moisture is lost and when ploughed up the clods are not easily reduced under the *sohaga*. Such rough lands easily lose their moisture after sowing. A ploughing just before or during the *hathia* is a great advantage as any shortness in the monsoon can thus be made up and a good germination ensured. A few days before sowing the land is ploughed up and instantly covered in with the *sohaga* so that the minimum of moisture is lost. The same procedure is adopted at sowing time and the land is quickly pressed down and consolidated. It will thus be seen that the tilth for wheat, sown in October, is obtained during the previous hot weather and never lost subsequently. The monsoon cultivation merely serves to make the soil take in more water, to keep down weeds and to pack the subsoil. The moisture absorbed is not lost in preparation just before sowing as is so commonly the case in India. A good example of the effect of conserving the monsoon rains and the *hathia* occurred in 1908. In this year the monsoon was exceedingly short and only 22 inches fell during the whole year before sowing time. In spite of this and the failure of the winter rains a crop of over 25 maunds of wheat to the acre was grown at Pusa without irrigation. The cultivators' crops failed almost entirely and a famine was declared in the District.

Improvement of the physical condition of the soil.—Wheat land is greatly improved in physical condition by an occasional green manuring combined with hot-weather cultivation. For this *san* (*Crotalaria juncea*, L.) is sown on the early showers of June and ploughed in early in August. For wheat the crop should not be allowed to get too woody as the stems do not decay in time and thus tend to keep the surface too open. Provided the hot-weather cultivation is efficient this green manuring need only be done occasionally.

Embanking has a great effect on the tilth and free working of the soil. To embank land a trench about two or three feet deep is dug round the field and the soil is thrown up on the inside and afterwards levelled so that the edges of the field are a few inches above the general level. This raised rim holds up water sufficiently to prevent surface wash. The trenches protect the fields from the water which drains off higher lands. The land has to deal only with its own rainfall and waterlogging is prevented. If it is desired to hold up all the rainfall, as for example during the *hathia* after a very bad monsoon, the rim of the field is slightly raised and all run-off is prevented. A great improvement in texture follows embanking, but we are unable at present to suggest a complete explanation.

The methods described at Pusa in wheat growing could be adopted in their entirety in Oudh and Bihar even when it is the rule to grow two crops in one year. Hot-weather cultivation in such circumstances would enable the *kharif* crops to be sown on the early showers and the well aerated soil would help to promote rapid growth. After the crop is removed the land should be opened up instantly and everything should be done to absorb water as rapidly and completely as possible. Last year on one of the estates in Bihar Pusa 20 gave a yield of 24 maunds to the acre after early maize in spite of the fact that this wheat requires more water than the other Pusa wheats and suffered in this particular case from the hot winds just before harvest. It is quite possible, however, that it might pay on wheat lands in Bihar to grow one good crop of wheat a year rather than to produce two small crops on the same land.

The Pusa method could be easily adapted to the other regions of the Indo-Gangetic where wheat is grown largely by canal water. Hot-weather cultivation can easily be carried out and occasional green manuring presents no difficulty. Whether embanking is necessary in the absence of the danger of surface wash we cannot say.

CHAPTER 4.

The Yielding Power of the New Pusa Wheats.

In general the yield of a variety of wheat is of more importance than the quality of its grain. High quality of grain unless combined with good cropping power is of little or no advantage to the cultivator. In a previous paper we have discussed the question of yield of wheat in India and have shown that the length of the growth period and also the water supply are limiting factors antagonistic to the cultivation of high tillering and high yielding wheats such as are grown in Northern Europe. Another limiting factor has since been discovered, namely, strength of straw. Few of our Indian wheats can carry a crop of over forty bushels to the acre unless the straw is assisted by cementing the soil by at least one irrigation. At present in dry cultivation the yields are limited by the strength of the straw.

At Pusa during the season of 1909-10 the yields of grain and straw of the wheats which have been tested in England were compared. For this purpose an area of even land was laid out in oblong quarter-acre plots (four by one) and the behaviour of the wheats in all respects was carefully noted. The plots were separated on the longer sides by one row of gram while the two shorter sides were next the grass borders of the fields. Grown next to grass in this way the outside edges of the wheat plots do not thrive so well as the inside portions and in this way the "edge-effect" is eliminated. The results of the trials are given in the following table:—

Variety trials of wheat at Pusa in 1909-10.

No.	Name.	Yield of Grain per acre.			Yield of Straw per acre.		
		Mds.	Srs.	Bushels. 1 Bushel = 60 lbs.	Mds.	Srs.	Cwts.
1	Pusa 106	34	17	47·2	85	15	62·7
2	Pusa 12	32	8	45·0	70	30	52·0

Variety trials of wheat at Pusa in 1909-10—contd.

No.	Name.	Yield of Grain per acre			Yield of Straw per acre.		
		Mds.	Srs.	Bushels. 1 Bushel, =60 lbs.	Mds.	Srs.	Cwts.
3	Muzaffarnagar	31	35	43·0	63	0	46·3
4	Pusa 11	30	22	41·9	68	10	56·1
5	Pusa 7	30	3	41·2	62	20	45·9
6	Pusa 8	30	0	41·1	86	6	63·3
7	Pusa 20	26	17	36·2	65	33	48·4
8	Pusa 21 (Hara)	25	35	35·5	70	0	51·1
9	Pusa 6a	25	0	34·3	64	27	47·5
10	Pusa 4	23	21	32·3	56	8	41·3
11	Pusa 22 (White Jana Khar) . .	23	15	32·0	41	32	31·0
12	Pusa 6	22	35	31·4	62	0	45·5
13	Pusa 23 (Red Jana Khar) . .	21	26	29·7	43	8	31·7
14	Pusa 3	20	23	28·2	46	17	33·8

The standard maund is made up of 40 seers and is equivalent to 82·28 lbs.

In considering the results it must be noted that the plot of Muzaffarnagar was unduly favoured and that while the rest of the wheats had to maintain themselves on the moisture absorbed by the soil during the previous monsoon this particular plot was watered once by mistake. Not only was the water an advantage but the cementing of the soil assisted the straw to stand up and so ripen the grain. A weak strawed wheat like this kind would not support a crop of nearly 32 maunds to the acre if grown under dry cultivation and without the assistance of the cemented surface.

Three of the wheats, Pusa 100, Pusa 101 and Pusa 102, were not grown on quarter-acre plots in 1909-10, but only on much smaller areas of $\frac{1}{16}$ of an acre each. Consequently their yields cannot be

compared with the above results on account of the much larger error involved in the calculations. They however gave exceedingly large crops for $\frac{1}{16}$-acre plots and promise to yield as high or even higher than Pusa 106. All of these wheats with the exception of Muzaffarnagar, Pusa 3 and Pusa 11 have given grain of very good milling qualities. All with the exception of Muzaffarnagar have behaved well in the baking tests. The behaviour both in the field and in the mill of Pusa 106, which was obtained by crossing Muzaffarnagar white and Pusa 6, shows that it is possible to combine high quality and high yield by the application of modern methods of plant breeding. Such a combination had long been considered impossible but the work done at Cambridge and Pusa shows that this position is an unsound one. The problem of producing wheats most suitable for consumption in India and for the export trade and at the same time most profitable to the growers has now been solved and all that remains to be done is to arrange for the distribution of these wheats to the cultivators in those tracts of India which suit the requirements of these particular kinds. Work is already in progress to discover experimentally which tracts in the plains are best suited for the purpose.

It will be noticed that the first six wheats on the list have given exceedingly high yields of grain and straw, the yields approaching what is considered a very good crop in England. The last five wheats on the list, although giving exceedingly good yields for India, do not possess the same cropping power as the first six. The remaining three occupy an intermediate position. Duplicate quarter-acre plots of several of these wheats were weighed at Pusa in the past season and the results agreed, within the limits of experimental error, with those given in the above table. The figures obtained in the present year are considered to represent substantially the relative yielding powers of the varieties tested with the exception of Muzaffarnagar white which was unduly favoured and Pusa 4, which, with thicker sowing, would probably have given a higher yield. This wheat is exceedingly early and might be found suitable for late sowing or in tracts where the amount of moisture is small. It does not use up the whole of the growth period at Pusa and is too early for the locality. Pusa 3 is also too early for Pusa. In addition its poor

milling qualities and low yield render it unsuitable for further trial in the alluvium.

Among the wheats at the bottom of the list are to be seen three kinds (Pusa 6, Pusa 22 and Pusa 23) which have behaved particularly well in the milling and baking tests. These had been previously selected as strong parents for crossing with Muzaffarnagar white and Punjab Type 9. We have now combined the good grain qualities of these three Pusa wheats with the high yielding power of the Muzaffarnagar and Punjab Type 9. Pusa 6 possesses one disadvantage which renders it unsuitable for cultivation in India, namely, its inability to hold its grain during the west winds. A large amount is always shed and remains on the field. A further quantity is lost on the way to the threshing floor. This unfavourable characteristic is not met with in all the progeny (possessing fixed characters) of the cross with Muzaffarnagar. Pusa 6 is, however, very rust resistant, has exceedingly good grain and for these reasons has been a most useful wheat especially as a parent.

We consider that the most useful wheats we have so far isolated at Pusa are the selections Pusa 7, Pusa 8 and Pusa 12 and the new hybrids obtained from Muzaffarnagar and Punjab Type 9 by crossing these high yielding wheats with some of the strongest Pusa selections. We now possess at Pusa a very wide range of wheats and it is quite possible they will be found useful for a large area of the Indo-Gangetic system.

CHAPTER 5.

The Experiments now in Progress.

At a large number of stations in the plains the new Pusa wheats are being grown this year and several planters in Bihar have arranged an extensive trial of the new selections and hybrids under estate conditions. Three of the Pusa wheats (Pusa 8, Pusa 12 and Pusa 22) have been selected for the work at ten stations on the influence of the environment on the milling and baking qualities of wheat in India, an investigation which is being conducted in collaboration with Mr. H. M. Leake, Economic Botanist to the Government of the United Provinces. It is expected that at the end of the present season a large amount of information will be available on the behaviour of these wheats outside Pusa when grown under the particular conditions now obtaining at each centre. The results obtained will not finally settle the possibility or otherwise of growing free-milling strong wheats in the various tracts as some modifications in the present practices might well be necessary in the future in order to produce optimum results. Our own experience at Pusa might be cited in this connection. Four years ago we had great difficulty in obtaining seed at all in some cases on account of the damage done by rust resulting partly from defective procedure in growing the crop. Since that time great progress has been made in the growing of wheat and we have since produced samples superior to those obtained from localities in India in which wheat can be grown to perfection much more easily than at Pusa.

In order to obtain such high yields and quality as have been realised at Pusa similar care in the preliminary cultivation and especially in hot-weather cultivation will be necessary. Water must be conserved as much as possible and caution will have to be exercised in keeping the irrigation down to the lowest limit. In other words common sense must be applied to the production of the crop and modifications in present practices will be necessary.

Reference has been made to two shortcomings of the wheats at present grown in India. These are want of standing power

of the straw and want of rust-resisting power. To make any additional progress in the improvement of Indian wheats these two problems will have to be solved and work is now in progress in this direction at Pusa.

Some of the new Pusa wheats, *e.g.*, Pusa 7, Pusa 8 and the new hybrids obtained from Punjab Type 9 possess straw considerably stronger than the average. Others will not carry crops of above 40 bushels to the acre really well unless the ground is cemented by irrigation. The high winds which occasionally blow in January and February when the crop is in ear do great damage to the weak strawed wheats and especially to those on the late side. The earlier crops in which the hardening process has begun are not laid to anything like the same extent as those in the soft green stage. Speaking generally we have reached the limit of wheat production at Pusa until the strength of the straw has been improved and hybridization work on these lines is now in progress. Fortunately we possess several wheats with strong straw and high grain characters which have been used for the work.

In addition to the work on the production of wheats with stronger straws by hybridization we are this year trying to increase standing power by growing suitable mixtures of weak and strong strawed wheats of the same milling grade. Mixing varieties of wheat is an old agricultural practice in many parts of the world and it is possible that it is a very sound one.[1] The mixtures however must be made with judgment and for a definite end.

Another direction in which progress can be made is in rust-resistance. Although many of the wheats at Pusa possess considerable resisting power to rust we have no variety which resists rust at Pusa to the same extent as American Club or Einkorn. Emmer is perhaps the most rust-resistant Indian wheat at present, but this is by no means immune to yellow rust (*Puccinia glumarum*, Eriks. & Henn.) as we found on examining plots of this wheat grown by Mr. Humphries at Weybridge in England in June 1910. Unfortunately American Club when grown at Pusa comes into ear much too late to be used as a parent in India while Einkorn does not form ears at all. To get over this difficulty we were

[1] See Howard and Howard, *Wheat in India*, p. 75, and Beaven, *Journal of the Roy. Agr. Soc. of England*, 1909, p. 119.

fortunate enough to obtain the assistance of Professor Biffen of Cambridge in the work of producing new rust-resistant wheats for India. In the spring of 1910 several of the Pusa wheats were sent to Cambridge where they were sown by Professor Biffen. The resulting plants were crossed on to American Club and other rust-resistant wheats by us at Cambridge last June and the F_1 generation is now being grown at Pusa and at Cawnpore, while a few of the ears will be sown at Quetta in case no crop is obtained in the plains. In this way, thanks to the valuable help rendered by Professor Biffen at Cambridge and by the Government of India in granting one of us deputation leave in England, the difficulties of hybridization have been got over and there is every hope that the rust problem in the plains will now be solved and that India will soon possess real rust-resisting wheats.